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Patentanmeldung Nr. Patent application No. Demande de brevet n°

02023012.4

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For the President of the European Patent Office

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p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 02023012.4
Demande no:

Anmeldetag:
Date of filing: 15.10.02
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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Input inrush current control and/or output short-circuit control to a boost converter in a power supply

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

H02H/

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

EP 25424-03590/W 15.10.2002

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INPUT INRUSH CURRENT CONTROL AND/OR OUTPUT SHORT-CIRCUIT CONTROL TO A BOOST CONVERTER IN A POWER SUPPLY

INPUT INRUSH CURRENT CONTROL AND/OR OUTPUT SHORT-CIRCUIT CONTROL TO A BOOST CONVERTER IN A POWER SUPPLY

The present invention relates to an electronic circuit for limiting an input inrush and/or short-circuit current supplied to a boost converter in a power supply and to a power supply with a boost converter comprising the electronic circuit. The electronic circuit can be connected between the input lines of an alternating input current source and the input lines of the boost converter and comprises a rectifier circuit to rectify the alternating input current of the alternating input current source.

In many power supplies there are voltage and current limiters in order to suppress undesirable and spurious current and voltage spikes. Sometimes the voltage spikes are generated by electrical equipment using the same power line, often the transient surges are caused by the power supply being quickly switched on and off or vice versa. Other causes for transient surges are also known in the art.

In order to avoid damage to the power supply, inrush current should be suppressed. In many conventional power supplies there is an input capacitor or a capacitor bank that charges when initially powered up. In this situation, the capacitor or the capacitor bank acts as a short-circuit and does not limit input current resulting in the actuation of a circuit breaker or even overloading a circuit near the power input by the inrush current.

To reduce the inrush current most conventional power supplies include elements to limit the initial input current flowing into the circuit. It is known in the art to use thermistors and relays to limit the inrush current. However, a thermistor cannot be used in large power supplies because the current load flowing through the thermistor may cause the destruction of same. Therefore, thermistors have been replaced with a common resistor shunted by a triac or silicon controlled rectifiers (SCR).

US-5 420 780 discloses a circuit for limiting the inrush current in a DC power supply. The inrush limiting circuit should be placed between the AC input power lin and a power supply input capacitor bank. A thermistor is located between the capacitor bank and the input diode bridge to limit the initial inrush current. Once th input capacitor bank is fully charged, an insulated-gate bipolar transistor (IGBT) switches

the rectified line voltage to a boost power factor correction converter circuit to block the thermistor by means of a diode. This switching keeps the thermistor cold to maintain high resistance in case of a new off/on cycle.

Another circuit for limiting the inrush current is shown in US 6,055,167. In the shown circuit, the input inrush current is reduced by phasing up the input voltage in a controlled manner. The circuit uses a silicon controlled rectifier (SCR) in the input bridge of the circuit to control the input inrush current at no additional losses.

A further problem often encountered when designing power supplies is the high current flowing through the power supply when short-circuiting the DC outputs. In conventional power supplies, additional high voltage switches are employed to solve this problem. High current peeks and very high currents in the circuit may otherwise cause a malfunction or even a destruction of the power supply.

For the above reasons, it is the object of the present invention to provide an electronic circuit used to limit the input inrush current in a power supply as well as limiting the short-circuit current when short-circuiting the DC output of the power supply and at the same time to reduce costs and/or the complexity of the electronic circuit.

According to the invention, the above-stated object is achieved by employing a feedback circuit for feeding back a switching signal to the rectifier circuit of the electronic circuit. Using a switching signal through a feedback loop in the feedback circuit allows to switch the operation of the rectifier circuit on/off and thereby to control the inrush current supplied to a boost converter as well as to limit the short-circuit current.

To generate the switching signal, the feedback circuit according to a first embodiment comprises a feedback inductance, which is inductively coupled to an input inductance of the boost converter. Thereby the switching signal can be effectively provided.

The feedback circuit further comprises two resistors both connected to the feedback inductance wherein the switching signal is fed over each of the resistors to respective rectifying elements of the rectifier circuit and wherein the feedback inductance of the feedback circuit is further connected to the current supplying output of the rectifier circuit. This layout of the elements of the feedback circuit allows to advantageously

feed back a switching signal to the switch, putting the switch into a conductive or non-conductive state.

In a further embodiment, it is of advantage to control the switching of the rectifier circuit and in this respect the switching signal, by adapting the ratio of the number of windings of the feedback inductance of the feedback circuit and the number of windings of the input inductance of the boost converter to determine the switching signal.

To provide an even better control of the input inrush current and the short-circuit current, the electronic circuit preferably comprises a current limiting circuit that limits the current supplied to the boost converter whereby the current limiting circuit is connected across the input lines of the input current source and to the current supplying output of the rectifier circuit.

In case the rectifier circuit is switched off by the switching signal, the current limiting circuit supplies a limited input current to the used converter.

In case the rectifier circuit is switched on by the switching signal, the rectifier circuit supplies a rectified input current to the boost converter. This behavior is advantageous as it allows to supply current to the boost converter depending on its demand.

In this first embodiment, the rectifier circuit is designed as a bridge circuit, comprising at least two rectifying elements that can be switched on/off. The bridge circuit convert a AC input signal into a rectified output signal and provides a reliable and cost effective implementation of a rectifier circuit.

In order to provide a rectified input current to the boost converter via the current limiting circuit, the current limiting circuit comprises two rectifying elements each connected to one of the two input lines of the alternating current source and both connected to a current limiter whereas the output of the current limiter is connected to the current supplying output of the rectifying circuit.

The rectifying elements can be diodes and the current limiter may be a resistance, a variable resistance or another element that output up to a maximum current. Alternatives are for example thermistors, in particular PTC thermistors as those limit

their own dissipation and allow permanent short-circuit control with very low internal dissipation. Thus, reliable standard components of low price may be used.

In a second embodiment of the present invention, an electronic circuit for limiting an inrush current supplied to an input of a boost converter in a power supply is disclosed. In this embodiment, the electronic circuit can be connected between the input lines of an alternating input current source and the input lines of the boost converter whereby the electronic circuit comprises a rectifier circuit to rectify the alternating input current of the alternating input current source and a switch connected between a current supplying output of the rectifier circuit and an input of the boost converter for controlling the current supply to the boost converter.

As the first embodiment, the second embodiment also solves the object of th present invention by employing a feedback circuit for feeding back a switching signal to the switch. The feedback circuit is further comprised by the electronic circuit. To generate the switching signal, the feedback circuit comprises a feedback inductance, which is inductively coupled to an input inductance of the boost converter.

The feedback circuit further comprises a resistor connected to the feedback inductance wherein the switching signal is fed over the resistor to the switch and wherein the feedback inductance of the feedback circuit is further connected to the output of the switch. This layout of the elements of the feedback circuit allows to advantageously feed back a switching signal to the switch, putting the switch into a conductive or non-conductive state.

As in the first embodiment, the ratio of the number of windings of the feedback inductance of the feedback circuit and the number of windings of the input inductance of the boost converter is adapted to determine the switching signal. Based on the current flowing through the input inductance of the boost converter, the inductive coupling of the feedback inductance of the feedback circuit to the input inductance of the boost converter produces a switching signal for switching the switch.

For an even more effective input inrush current control and a short-circuit current control, it is advantageous to further provide a current limiter that limits the current supply to the boost converter and being in parallel to the switch in the electronic circuit.

In case the switch is switched off by the switching signal, the electronic circuit supplies a limited input current to the boost converter via the current limiter, whereas in case the switch is switched on by the switching signal, the electronic circuit supplies a rectified input current to the boost converter via the rectifier circuit.

According to an aspect of the invention, the rectifier circuit is a bridge circuit which comprises at least two rectifying elements, in order to convert an AC alternating input current into a rectified output signal. The rectifying elements can be diodes and the current limiter may be a variable resistance or a thermistor, advantageously a PTC (positive temperature coefficient) thermistor.

The electronic circuit can be favorably used in a power supply together with a boost converter wherein the rectifier circuit of the electronic circuit is connected between the input lines of the alternating current source and the input lines of the boost converter.

In a further aspect of the present invention, the boost converter is a boost power factor correction circuit comprising an input inductance, connected to the output of the rectifier circuit supplying current to the boost power factor correction circuit, a power switch, connected between the input inductance and the output of the rectifier circuit supplying no current to the boost power factor correction circuit, a diode, connected between the input inductance and the first output of the boost power factor correction circuit and a capacitance, connected between the first and second output of the boost power factor correction circuit.

By means of the advantageous embodiments shown in the figures, the present invention will be more closely described in the following. Similar or corresponding details are marked with the same reference signs in the figures.

Figure 1	shows a power supply with a boost converter comprising an electronic circuit according to a first embodiment,
Figure 2	shows a power supply with a boost converter comprising an electronic circuit according to a second embodiment.

Figure 1 shows the circuit diagram of a power supply with a boost converter 3 comprising an electronic circuit according to a first embodiment for limiting the input

inrush current and the shot-circuit current. The circuit comprises a rectifier circuit 1 which rectifies the AC input current signal supplied from the AC input terminals J1 and J2. In the figure, the rectifier circuit 1 is formed by a bridge circuit with four rectifying elements D1, D2, Q1, Q2, whereof two rectifying elements, Q1 and Q2, are controlled rectifiers which can be switched on or off, i.e. they are in conductive or non-conductive state, in response to a switching signal supplied by lines 5 and 6.

The other rectifying elements D1, D2 can be for example diodes as shown in the figure or operational amplifier circuits, which rectify the AC input signal delivered from the AC input terminals J1, J2.

The circuit shown in figure 1 further comprises a feedback circuit 2. The inductor I2 of the feedback circuit 2 is connected at one side to the current supplying output of the rectifier circuit forming the first output terminal of the bridge circuit. The current supplying output of the rectifier circuit is corresponding to junction point 7. The second output of the bridge circuit corresponds to junction point 10.

The feedback inductance I2 is further connected via two shunted resistors R1 and R2 to lines 5 and 6, providing the switching signal to the controlled rectifier elements Q1 and Q2. Thus, it is possible to feed back a switching signal through the feedback circuit 2 to the rectifier circuit 1 to switch its operation.

In order to generate the switching signal for switching the rectifier circuit 1, the boost converter 3 is connected to the outputs of the rectifier circuit 1. An input inductance I1 of the boost converter 3 is connected to the current supplying output of the rectifier circuit 1 and via a diode D3 to the first DC output terminal J3. Between the input inductance I1 and the diode D3 the input inductance I1 is further connected to a power switch Q1. The power switch can be any controllable switch or power switch, such as transistors. A power switch control 12 controls the switching of power switch Q1 by a control signal. Further, a capacitance C1 is connected between the DC output terminals J3 and J4. Instead of a single capacitor as shown in the circuit diagram of figure 1 a capacitor bank could also be used.

As the design of boost converters, especially boost power factor correction circuits is well known in the art, a more detailed description of the boost converter 3 is omitted.

A detailed description of a power factor correction circuit is for example shown in US 4,677,366.

The electronic circuit further comprises a current limiting circuit 4, which is connected across the input lines from the input current source (AC input terminals J1, J2) and to the current supplying output of the rectifier circuit 1. The current limiting circuit 4 comprises two rectifying elements D4, D5, which rectify the signals supplied from a AC power supply via the AC input terminals J1 and J2. Next, the rectified signals are passed through a current limiter R3. The current limiter R3 is further connected to the current supplying output of the rectifier circuit 1.

The operation of the electronic circuit according to the first embodiment and the switching of the rectifiers Q1 and Q2 by a switching signal will be more closely discussed in the following.

The switching signal is generated by the inductive coupling of the input inductance I1 of the boost converter 3 and the feedback inductance I2 of the feedback circuit 2.

If the power supply is turned on, the current will flow through the current limiting circuit 4 towards the boost converter 3 supplying up to a maximum input current to the boost converter 3. Thereby, the current limiter R3 is able to limit the input inrush current into the boost converter 3.

In this initial state, the diodes D1, D2, D4 and D5 build a bridge circuit that rectifies the input signal. The current supplying output (junction point 15) of this initial bridge circuit of the diodes D1, D2, D4 and D5 is connected via the current limiter R3 to the input of the boost converter 3. Hence, the input signal is supplied via the current limiter R3 to the boost converter 3 and is thereby limited.

If a load connected to the DC output terminals J3 and J4, consumes sufficient power, the inductive coupling of the input inductance I1 of the boost converter 3 will induce a sufficiently high voltage in the feedback inductance I2 of the feedback circuit 2. This induced voltage forms the switching signal that, in case the switching signal is sufficiently high, will bring the rectifier elements Q1 and Q2 into a conductive state. As soon as the rectifier circuit 1 is switched on by the switching signal, the maximum available power from the AC power source can be supplied via input terminals J1 and J2 and via the rectifier circuit 1 to the boost converter 3. Thus, the available power to

the boost converter 3, and in this respect to an attached load, is then only limit d by the available power of the AC power source.

In the state, in which the rectifier elements Q1 and Q2 are in a conducting state, the rectifier elements Q1 and Q2 and the diodes D1 and D2 build the rectifier (bridge) circuit 1. Thus, rectifier elements Q1 and Q2 directly supply the input signal to the input of the boost converter 3.

In case, the DC output terminals are short-circuited, the voltage at the input inductance I1 of the boost converter 3 will drop to zero volts. Hence, no voltage will be induced to the feedback inductance I2, which leads to switching off the rectifier circuit 1, or in more detail as shown in figure 1, to switching off the rectifier elements Q1 and Q2. In this case, power from the AC input terminals J1 and J2 is only supplied to the boost converter 3 via the current limiting circuit 4.

In contrast to the situation where the rectifier circuit 1 is switched on and supplies up to the maximum power of the AC power source to the boost converter 3, only a limited current can be delivered to the boost converter 3, as current limiter R3 will limit the current flowing into the boost converter 3. Hence, the short-circuit current in the power supply can be efficiently controlled.

Figure 2 shows a circuit diagram of a power supply with a boost converter 3 comprising an electronic circuit for limiting the input inrush and shot-circuit current according to a second embodiment of the present.

The AC input terminal J1 and J2 are connected to a rectifier circuit 1. The rectifier circuit 1 shows a similar bridge layout as in the previous embodiment. The rectifier circuit 1 comprises four rectifying elements D1, D2, D4, D5. The power supplying output of the rectifier circuit 1 (junction point 14) is connected via a controlled rectifier Q1 to the boost converter 3. Also there is a current limiter R3 in parallel to the controlled rectifier Q1.

The power supply further comprises a feedback circuit 2, which comprises a feedback inductance I2 and a resistor R1. The feedback inductance I2 is connected between the resistor R1 and junction point 16, which is located between the controlled rectifier Q1 and an input inductance I1 of the boost converter 3.

The resistor R1 is further connected via a switching signal line 13 to the controlled rectifier Q1. Through line 13, a switching signal can be applied to the controlled rectifier Q1 which operates as a switch. The boost converter 3 comprises the same elements as in the first embodiment. Therefore, its detailed description is omitted.

As in the first embodiment, the switching signal is provided by the inductive coupling of the input inductance I1 of the boost converter 3 and the feedback inductance I2 of the feedback circuit 2.

During operation, in case the power supply is turned on, the rectifier circuit 1 will rectify the input signal supplied from the AC input terminals J1 and J2 and the rectified input signals are passed via the current limiter R3 to the boost converter 3.

The switch (controlled rectifier Q1) is initially turned off, as no voltage drops across the input inductance I1 of the boost converter 3, resulting in no induced voltage in the feedback inductance I2, which could switch the switch Q1 on.

In case a load attached to the DC output terminals J3 and J4, consumes sufficient power, such that the voltage at the input inductance I1 of the boost converter 3 is sufficiently high, an induced voltage in the feedback inductance I2 of the feedback circuit 2 will bring the switch (controlled rectifier Q1) in a conductive state. In this case, the total current supplied to the boost converter will flow through the controlled rectifier Q1 as it presents a neglectable resistance compared to the current limiter R3.

The current limiter may be a variable resistor a normal resistor or the like. Any element that limits an input current to a maximum level and that can be operated in a power supply is suitable to be employed as a current limiter in the shown circuit.

In case the power supply shown in figure 2 is switched on, an input inrush current is limited by the current limiter R3 as the switch Q1 is initially in a non-conductive state. Thus, the input inrush current can be effectively controlled by current limiter R3.

In case the DC output terminals J3 and J4 are short-circuited, the diode D3 and the boost converter 3 will clamp the input inductance I1 of the boost converter to zero volts, thus switching the controlled rectifier Q1 in an off state. In this case, the current supplied from the AC power source to the boost converter 3 will have to flow through

the current limiter R3, which will limit the maximum current flowing into th boost converter 3. Therefore, the short-circuit current of the power supply can be effectively controlled.

It is important to recognize that in the first as well as in the second embodiment of the electronic circuit, the switching signal can be for example influenced by the number of windings N1 of the input inductance I1 of the boost converter 3 and the number of windings N2 of the feedback inductance I2 of the feedback circuit 2. The induced voltage V_{I2} of the feedback inductance I2 is proportional to the ratio of the number of windings N2/N1 times the voltage V_{I1} of the input inductance I1 of the boost converter 3. Thus, by choosing the appropriate ratio N2/N1 the switching voltage can b adapted to individual needs.

The switching signal and therefore the switching of the rectifiers Q1, Q2 (or the switch Q1) can be also influenced by the polarization of the windings N2 of the feedback inductance I2 of the feedback circuit 2, the threshold voltage of the rectifiers/switch Q1, Q2, the value of R1, etc.

Claims:

1. An electronic circuit for limiting an input inrush and/or output short-circuit current supplied to a boost converter (3) in a power supply, said electronic circuit to be connected between the input lines of an alternating input current source and the input lines of the boost converter (3), the electronic circuit comprising a rectifier circuit (1) to rectify the alternating input current of the alternating input current source,

   characterized in that

   the electronic circuit further comprises a feedback circuit (2) for feeding back a switching signal to the rectifier circuit (1).

2. The electronic circuit according to claim 1, characterized in that the feedback circuit (2) comprises a feedback inductance (I2), which is inductively coupled to an input inductance (I1) of the boost converter (3).

3. The electronic circuit according to claim 2, characterized in that the feedback circuit (2) further comprises two resistors (R1, R2) both connected to the feedback inductance (I2), wherein the switching signal is fed over each of the resistors (R1, R2) to respective controlled rectifying elements (Q1, Q2) of the rectifier circuit (1) and wherein the feedback inductance (I2) of the feedback circuit (2) is further connected to the current supplying output (7) of the rectifier circuit (1).

4. The electronic circuit according to one of claims 1-3, characterized in that the ratio of the number of windings (N2) of the feedback inductance (I2) of the feedback circuit (2) and the number of windings (N1) of the input inductance (I1) of the boost converter (3) and/or the polarization of the windings (N2) of the feedback inductance (I2) of the feedback circuit (2) is adapted to determine the switching signal.

5. The electronic circuit according to one of claims 1-4, characterized by further comprising a current limiting circuit (4) that limits the current supplies to the boost converter (3), the current limiting circuit (4) being connected across the input lines

of the input current source and to the current supplying output (7,8) of the rectifier circuit (1).

6. The electronic circuit according to claim 5, characterized in that the current limiting circuit (4) supplies a limited input current to the boost converter (3), in case the rectifier circuit (1) is switched off by the switching signal.

7. The electronic circuit according to claim 6, characterized in that the rectifier circuit (1) supplies an rectified input current to the boost converter (3), in case the rectifier circuit (1) is switched on by the switching signal.

8. The electronic circuit according to one of claims 1-7, characterized in that the rectifier circuit (1) is a bridge circuit comprising at least two controlled rectifying elements (Q1, Q2) that can be switched on/off.

9. The electronic circuit according to one of claims 5-8, characterized in that the current limiting circuit (4) comprises two rectifying elements (D4, D5), each connected to one of the two input lines of the alternating current source and both connected to a current limiter (R3), the output of the current limiter (R3) being connected to the current supplying output (7, 8) of the rectifier circuit (1).

10. The electronic circuit according to one of claims 3 to 9, characterized in that the rectifying elements (D1, D2, D3, D4) are diodes and the current limiter (R3) is a variable resistance or a thermistor.

11. An electronic circuit for limiting an input inrush and/or output short-circuit current supplied to a boost converter (3) in a power supply, said electronic circuit to be connected between the input lines of an alternating input current source and the input lines of the boost converter (3), the electronic circuit comprising a rectifier circuit (1) to rectify the alternating input current of the alternating input current source and a switch (Q1) connected between a current supplying output of the rectifier circuit (1) and an input of the boost converter (3) for controlling the current supplied to the boost converter (3),

characterized in that

the electronic circuit further comprises a feedback circuit (2) for feeding back a switching signal to the switch (Q1).

12. The electronic circuit according to claim 11, characterized in that the feedback circuit (2) comprises a feedback inductance (I2), which is inductively coupled to an input inductance (I1) of the boost converter (3).

13. The electronic circuit according to claim 12, characterized in that the feedback circuit (2) further comprises a resistor (R1) connected to the feedback inductance (I2), wherein the switching signal is fed over the resistor (R1) to control electrodes (13, 16) of the switch (Q1.

14. The electronic circuit according to one of claims 11-13, characterized in that the ratio of the number of windings (N2) of the feedback inductance (I2) of the feedback circuit (2) and the number of windings (N1) of the input inductance (I1) of the boost converter (3) and/or the polarization of the windings (N2) of the feedback inductance (I2) of the feedback circuit (2) is adapted to determine the switching signal.

15. The electronic circuit according to one of claims 11-14, characterized by further comprising a current limiter (R3) that limits the current supplies to the boost converter (3), the current limiter (R3) being in parallel to the switch (Q1).

16. The electronic circuit according to claim 15, characterized in that the current limiter (R3) supplies a limited input current to the boost converter (3), in case the switch (Q1) is switched off by the switching signal.

17. The electronic circuit according to claim 16, characterized in that the rectifier circuit (1) supplies a rectified input current to the boost converter (3), in case the switch (Q1) is switched on by the switching signal.

18. The electronic circuit according to one of claims 11-17, characterized in that the rectifier circuit (1) is a bridge circuit comprising at least two rectifying elements (D1, D2, D4, D5).

19. The electronic circuit according to claim 18, characterized in that at least one rectifying element (D1, D2, D4, D5) is a diode and the current limiter (R3) is a variable resistance or thermistor.

20. A power supply with a boost converter (3) comprising an electronic circuit according to one of claims 1-19 wherein the rectifier circuit (1) is connected between the input lines of the alternating input current source and the input lines of the boost converter (3).

21. The power supply according to claim 20, characterized in that the boost converter (3) is a boost power factor correction circuit, comprising:

an input inductance (I1), connected to the output of the rectifier circuit (1) supplying current to the boost power factor correction circuit,

a power switch (Q3), connected between the input inductance (I1) and the output of the rectifier circuit (1) supplying no current to the boost power factor correction circuit,

a diode (D3), connected between the input inductance (I1) and the first output (J3) of the boost power factor correction circuit and

a capacitance (C1), connected between the first (J3) and second (J4) output of the boost power factor correction circuit.

22. The power supply according to claim 20 or 21, characterized in that the feedback inductance (I2) of the feedback circuit (2) is inductively coupled to the input inductance (I1) of the boost power factor correction circuit.

Abstract

The present invention relates to an electronic circuit for limiting an input inrush and/or output short-circuit current supplied to a boost converter in a power supply. The electronic circuit can be connected between the input lines of an alternating input current source and the input lines of the boost converter and comprises a rectifier circuit to rectify the alternating input current of the alternating input current source. To limit the input inrush current in a power supply as well as limiting the short-circuit current when short-circuiting the DC output of the power supply and at the same time to reduce costs and/or the complexity of the electronic circuit, the electronic comprises a feedback circuit for feeding back a switching signal to the rectifier circuit. The present invention further relates to a power supply with a boost converter comprising the electronic circuit.

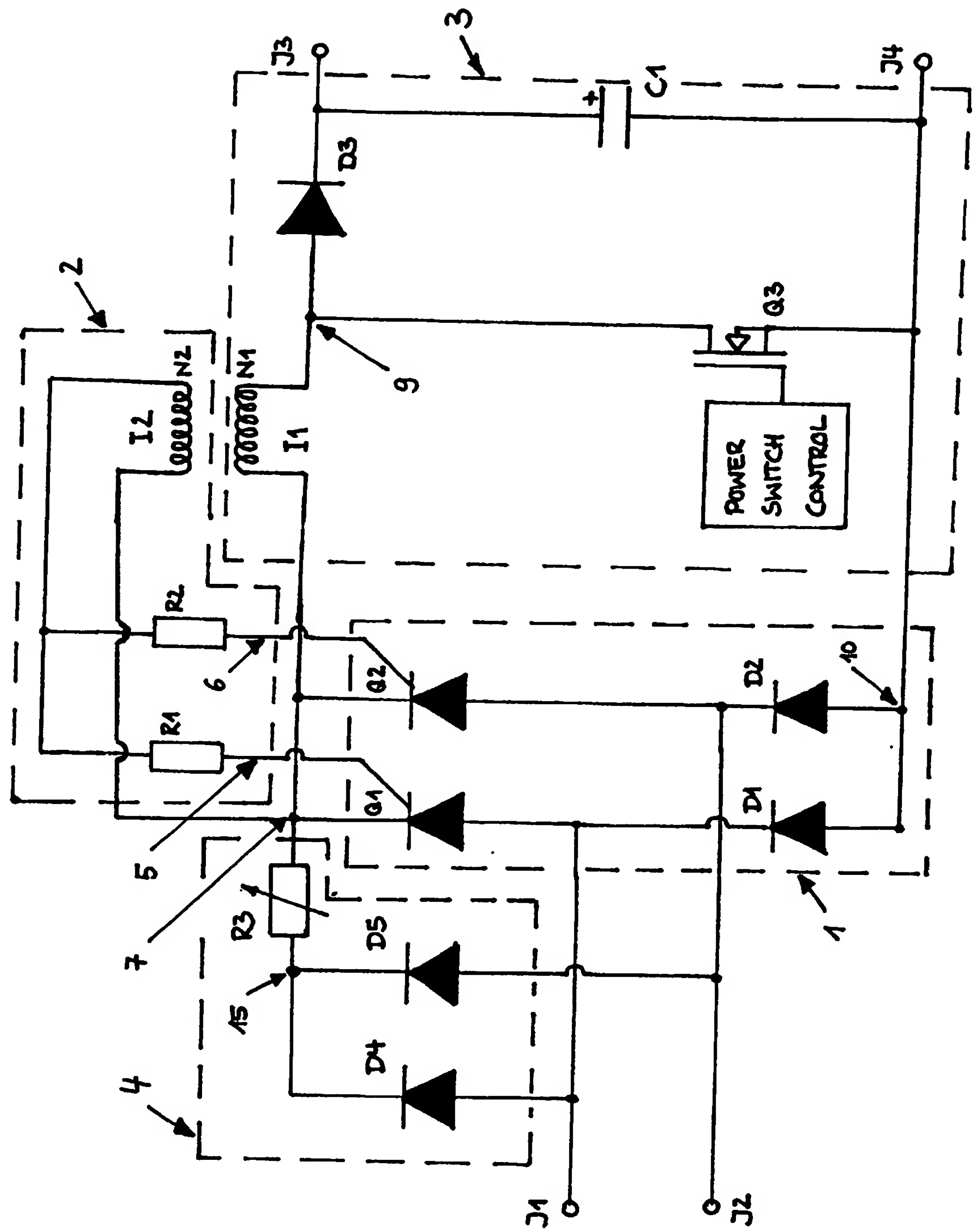
J3
J4
3
C1
D3
Q3
9
POWER SWITCH CONTROL
2
N2
N1
I2
I1
R2
R1
6
5
7
Q2
Q1
D2
D1
10
1
R3
D5
D4
15
4
J1
J2

FIG. 1

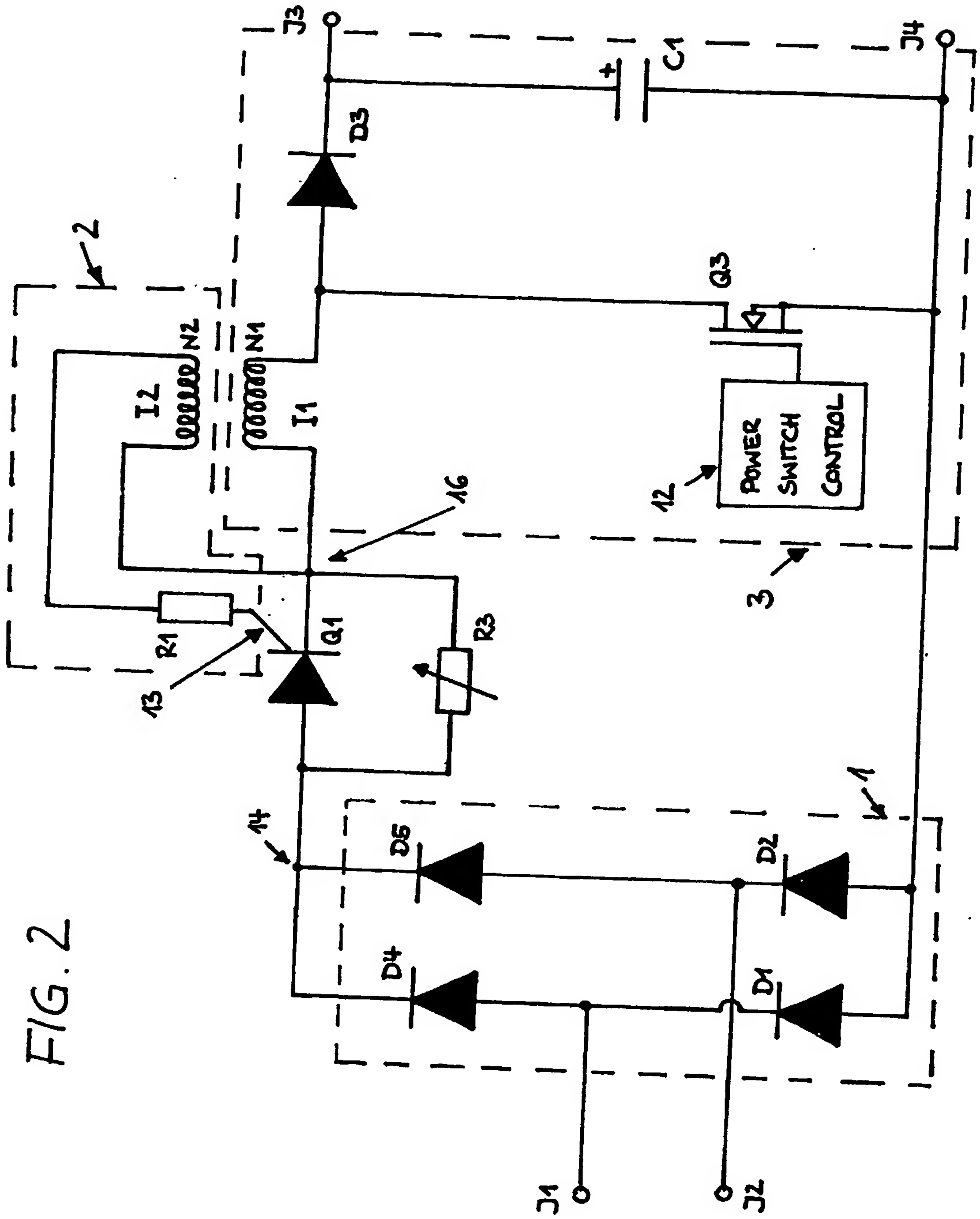
J3
J4
+
C1
D3
Q3
N2
N1
I2
I1
POWER
SWITCH
CONTROL
12
16
2
3
R1
Q1
R3
13
14
D5
D2
D4
D1
1
J1
J2

FIG. 2